

## Evidence review

# Low density development: Impacts on physical activity and associated health outcomes

Prepared by

Professor Billie Giles-Corti, B App Sc, M App Sc, PhD <sup>a</sup>

Dr Paula Hooper, BSc (Hons), MSc, PhD <sup>b</sup>

Dr Sarah Foster, BSc (Hons), PhD <sup>b</sup>

Dr Mohammad Javad Koohsari, BSc, MSc, PhD <sup>a</sup>

Dr Jacinta Francis, BSc, MPH, PhD <sup>a</sup>

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1300 36 27 87  
[www.heartfoundation.org.au](http://www.heartfoundation.org.au)

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<sup>a</sup>McCaughey VicHealth Centre for Community Wellbeing, The University of Melbourne

<sup>b</sup>Centre for the Built Environment and Health, The University of Western Australia

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## Executive Summary

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We found consistent cross-sectional evidence:

- **That those living in higher density neighbourhoods undertake more walking and physical activity than those living in low density neighbourhoods.**
- **Of positive associations between people's perceptions of higher densities and walking and cycling. However, few studies examined relationships between residential densities and other different types of physical activity and leisure behaviours.**
- **That living in low density neighbourhoods is positively associated with increased overweight and obesity in adults and adolescents, but the relationship with weight status in younger children is less clear.**

There was relatively consistent cross sectional evidence that:

- Residential density is associated with transport mode choice, with higher residential densities positively associated with active transport modes, and (in general) negatively associated with car dependency outcomes. Hence, living in low density housing developments is likely to increase car dependency with residents using fewer active modes of transport.

We found very limited evidence examining the direct relationship between residential density and cardiovascular outcomes. However, there was emerging evidence that low residential density development may be associated with an increased risk of coronary heart disease (CHD) independent of individual and area-level measures of socioeconomic status and that areas with a higher density of facilities used for habitual physical activity may reduce the risk of metabolic syndrome. **However, this is based on two studies only and further research is required in this area.**

There was less consistent evidence on the associations between residential density and children and adolescents' physical activity behaviours, and consequently firm conclusions cannot be drawn. The evidence available from the last five years however suggests that there may be differences in the impacts of residential density on children's physical activity level according to their age (i.e., children or adolescents).

Finally, we found insufficient evidence in the last five years to conclude that:

- Low density development results in more time in sedentary leisure-time pursuits and this warrants further exploration.

### **So what level of density is optimal from a cardiovascular health perspective?**

We found a limited evidence base from which to make clear recommendations on a minimum threshold for low density development. Nevertheless, based on the limited available evidence and consistent with case studies of planning practice, we make the following recommendations:

#### **Recommendations:**

1. While empirical evidence is limited, both a practice-based case study approach and one empirical study identified that a net density threshold of 20 dwellings per hectare (or gross density of 18 dwellings per hectare) is the minimum required to encourage at least some transport-related walking.
2. If an additional performance criteria required that densities are sufficient to make amenities and public transport viable on the basis that increased access to amenities and public transport will encourage more walking (as was shown in this report), densities of between 35-43 net and 32-40 gross dwellings per hectare (based on dwelling occupancies of 2.6 persons/dwelling) are required.
3. In making these recommendations it is critical to recognise that while density underpins the creation of walkable areas, density is necessary but insufficient alone to change health behaviours, and improve health outcomes. There is clearly a need to focus on *the combination of* built environment attributes required to create walkable neighbourhoods. In this report, we articulated these attributes based on the Ewing and colleagues' 6Ds: i.e., density, distance to transit, destination accessibility, diversity, design, and demand management. A minimum threshold of density underpins the success of many of these other built environment attributes. However, focussing on density in isolation without delivery of other built environment attributes that promote walking, will not achieve the desired outcome of creating cardiovascular health supportive environments. It is the cumulative and combined effects of these attributes that create the pedestrian-friendly areas required to increase levels of physical activity and in turn, reduce the risk of cardiovascular disease.

## Glossary

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|                              |   |
|------------------------------|---|
| Active transport             | Physical activity undertaken as a means of transport. May include walking, cycling, or other non-motorised vehicles. Also includes use of public transport where walking or cycling is required at the beginning or the end of the journey.   |
| ‘Big-box’ shopping centres   | The term "big-box" is derived from the store's physical appearance. Large, free-standing, generally single-floor structures with shops located internally and with limited exterior activation and that typically sit within large, paved parking lots.   |
| Burden of disease            | The ‘weight’ of disease borne by a community which is a reflection of morbidity, mortality, disability and reduced quality of life.   |
| Built environment            | Defined broadly to include land use patterns, the transportation system, and design features that together provide opportunities for travel and physical activity. Land use patterns refer to the spatial distribution of human activities. The transportation system refers to the physical infrastructure and services that provide the spatial links or connectivity among activities. Design refers to the aesthetic, physical, and functional qualities of the built environment, such as the design of buildings and streetscapes, and relates to both land use patterns and the transportation system. |
| Cardiovascular disease (CVD) | Cardiovascular disease (also called heart disease) is a class of diseases that involve the heart, the blood vessels (arteries, capillaries, and veins) or both.   |
| Coronary Heart Disease (CHD) | CHD is a narrowing of the small blood vessels that supply blood and oxygen to the heart. CHD is also called coronary artery disease.  |
| Connectivity                 | The directness of travel to destinations.   |



|                             |  |
|-----------------------------|--|
| Conventional development    | Development of this type is characterised by segregated land uses, low residential density subdivision-style development and poor connectivity of the street networks as a result of hierarchical, curvilinear street networks and culs-de-sacs being commonplace.   |
| Cross-sectional studies     | Studies that examine the relationship between conditions (e.g., physical activity behaviours) and other variables of interest in a defined population at a single point in time. Cross-sectional studies can quantify the presence and magnitude of associations between variables. Unlike longitudinal studies, however, they cannot be used to determine the temporal relationship between variables, and evidence of cause and effect cannot be assumed.                  |
| Cul-de-sac                  | A street, lane, or passage closed at one end.  |
| Curvilinear street patterns | Conventional neighbourhoods are developed around a network of hierarchical roads. Curvilinear roads terminating in cul-de-sacs (i.e., lollipop-shaped dead end roads) feed from large, high speed roads, creating low levels of connectivity. Residents have little or no choice of route, as often there is only one road in and out of the development, and the indirect curvilinear streets increase walking distances between destinations thereby discouraging walking. |
| Density                     | Typically measured as dwellings, employment or population per unit area.   |
| Green space                 | Land dedicated for public use, which may be parks, gardens, bush land, rivers or lakes, that provides an opportunity for sport and/or recreation, as well as being valued for aesthetic enhancement of an area.  |
| High density                | Over 60 dwellings per hectare <sup>1</sup> . It should be noted that definitions of density will vary slightly between jurisdictions.  |
| High rise                   | Five or more storeys.  |

|                            |   |
|----------------------------|---|
| Housing development/estate | A group of residential buildings planned and built together.  |
| Independent mobility       | The ability of children to traverse their neighbourhood independent of adult supervision.   |
| Land use mix.              | Diversity or variety of land uses (e.g., residential, commercial, industrial).  |
| Longitudinal study         | A scientific study that follows a group of participants over time and in which the exposure and outcome measures can be temporally sequenced.   |
| Low density                | <25 dwellings per hectare and single residential housing <sup>1</sup> . It should be noted that definitions of density will vary slightly between jurisdictions.  |
| Low rise                   | Two storeys or less.  |
| Medium density             | Generally between 25 and 60 dwellings per hectare and not usually more than three or four storeys in height <sup>1</sup> . It should be noted that definitions of density will vary slightly between jurisdictions. |
| Medium rise                | Three to four storeys in height.  |
| Mixed density              | Co-location of multi-dwelling housing (such as flats) alongside townhouses and single-dwelling structures, catering for a range of preferences and housing budgets.   |
| Mixed use                  | Incorporation of residential and retail structures in the same geographic location.   |
| Natural experiments        | Situations in which different groups in a population have differing exposures and can be observed for different outcomes.   |
| Nonmotorized travel        | Travel by nonmotorized means, including walking, cycling, small-wheeled transport (e.g., skates, skateboards, push scooters, hand carts), and wheelchair.   |

|                     |  |
|---------------------|--|
| Physical activity   | Bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above the basal (i.e., resting) level.  |
| Self-selection bias | In lay terms, refers to the need to distinguish the roles of personal attitudes, preferences, and motivations from external influences on observed behaviour. For example, do people walk more in a particular neighbourhood because of pleasant tree-lined sidewalks, or do they live in a neighbourhood with pleasant tree-lined sidewalks because they like to walk? If researchers do not properly address this issue by identifying and separating these effects, their empirical results will be biased in the sense that features of the built environment may appear to influence physical activity more than they do. |
| Urban fringe        | The outermost perimeter of an urban area, where urban and rural or semi-rural land uses meet.  |
| Urban sprawl        | The organic and often unplanned growth of a city from a high-density centre, to increasingly low-density fringes that encroach into rural areas.   |
| Urbanisation        | The degree to which an area is developed by urban amenities including residential, retail, commercial and transportation.  |
| Walkability         | The extent to which a neighbourhood encourages and supports walking for transport and recreation.  |

# 1. Introduction

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In the last decade, there has been growing interest in the impacts of city planning and urban design, on health and wellbeing outcomes. City planning and urban design directly and indirectly influence health and health behaviour outcomes via a number of pathways. They affect whether residents have access to local shops and services, footpaths and cycle paths (hence how easily they can walk or cycle locally); whether jobs are co-located near housing and whether residents have access to public transport (impacting the mode and time spent commuting to work); whether neighbourhoods are exposed to traffic, and therefore whether children can walk safely alone to and from school; and whether local recreational opportunities are healthy-enhancing (e.g., parks or sports centres) or health-damaging (e.g., focussed on alcohol and/or gambling). All of these outcomes, directly or indirectly impact the health and wellbeing of citizens by encouraging or discouraging physical activity (principally through walking or cycling), and sedentary behaviour (including time spent driving). This in turn impacts chronic disease profiles including cardiovascular disease outcomes.

Importantly, neighbourhoods with health-enhancing characteristics have been shown to be valued by consumers. A study of new home buyers found that while the affordability of housing is generally rated as the most critical factor in housing choice for new home buyers, aspects of neighbourhood walkability (e.g., access to local shops, public transport and pedestrian friendliness) are also highly valued <sup>2</sup>. Moreover, a national Newspoll telephone survey of 1400 Australians aged over 18 years commissioned by the Heart Foundation on whether healthy neighbourhood features influenced their decision about where to live, found that:

1. Being within easy walking distance of public transport was the ***most often ranked highest priority***, with almost 70% of participants reporting as extremely or very important; and
2. 64% reported that being within easy walking distance to a range of local services would be extremely or very important.

Consistent with the Heart Foundation findings, a survey of over 700 residents of Sydney and Melbourne, by the Grattan Institute <sup>3</sup> found four broad categories of dwelling and neighbourhood features that mattered most to consumers. Apart from dwelling characteristics (e.g., the number of bedrooms), neighbourhood attributes perceived to be most important included: *convenience and access* (i.e., work and health services, friends

and family); *neighbourhood attractiveness* (e.g., near a park, clean and unpolluted, and attractive natural environment) and *safety and security*. A Western Australian report built on the Grattan Institute's report found that ease of access to childcare and schools, shops and services, as well as easy access to work (not necessarily proximity) were highly valued. <sup>4</sup>

Although housing affordability is a major driver of housing demand, consumers prefer to live in neighbourhoods with local amenities. Thus, in a series of reports, the Grattan Institute has explored factors driving the supply of housing, and found a mismatch between what is provided and the types of housing consumers would choose if it was available. As observed by the Grattan Institute, new low density greenfield communities are heavily dependent on motor vehicles due to a shortage of public transport <sup>5</sup>. Typically, they also lack social infrastructure such that 'meeting the demand for childcare, school places, recreation and social services remains a major challenge in growth areas'<sup>5</sup>.

A major contributing factor to the shortage of public transport and the lack of social infrastructure on the urban fringe of cities is the prevailing *level of low density housing* in greenfield areas. For example, detached family housing predominates greenfield developments: 88 percent of homes in rapidly growing new growth areas are detached compared with 76 per cent nationally <sup>5</sup>. Delivering local public transport and social infrastructure in low density is challenging because the housing is spread over a wide area, and the population is too low to make mixed use planning and public transport viable. Low density housing development also discourages local walking and cycling, and requires more time being spent driving.

Previous Heart Foundation reports have observed: "*Neighbourhood design plays an important role in supporting healthy communities by encouraging physical activity and community interaction*" <sup>6</sup>. Given the economic and social burden of community levels of heart disease, urban and transport planning that encourages walking, cycling and public transport are passive interventions impacting whole populations and could help optimise cardiovascular health outcomes <sup>7-10</sup>.

Urban and transportation planners have attempted to categorise urban design features that are required to encourage more walking, cycling and public transport use into the six 'D's: density, diversity, design, distance to transit, destination accessibility and demand management <sup>11</sup>. Density is clearly a critical factor, as it underpins the delivery of three other 'D's (i.e., distance to transit, diversity and destination accessibility) and is related to another 'D' (i.e., neighbourhood design). For example, without a minimum threshold of population

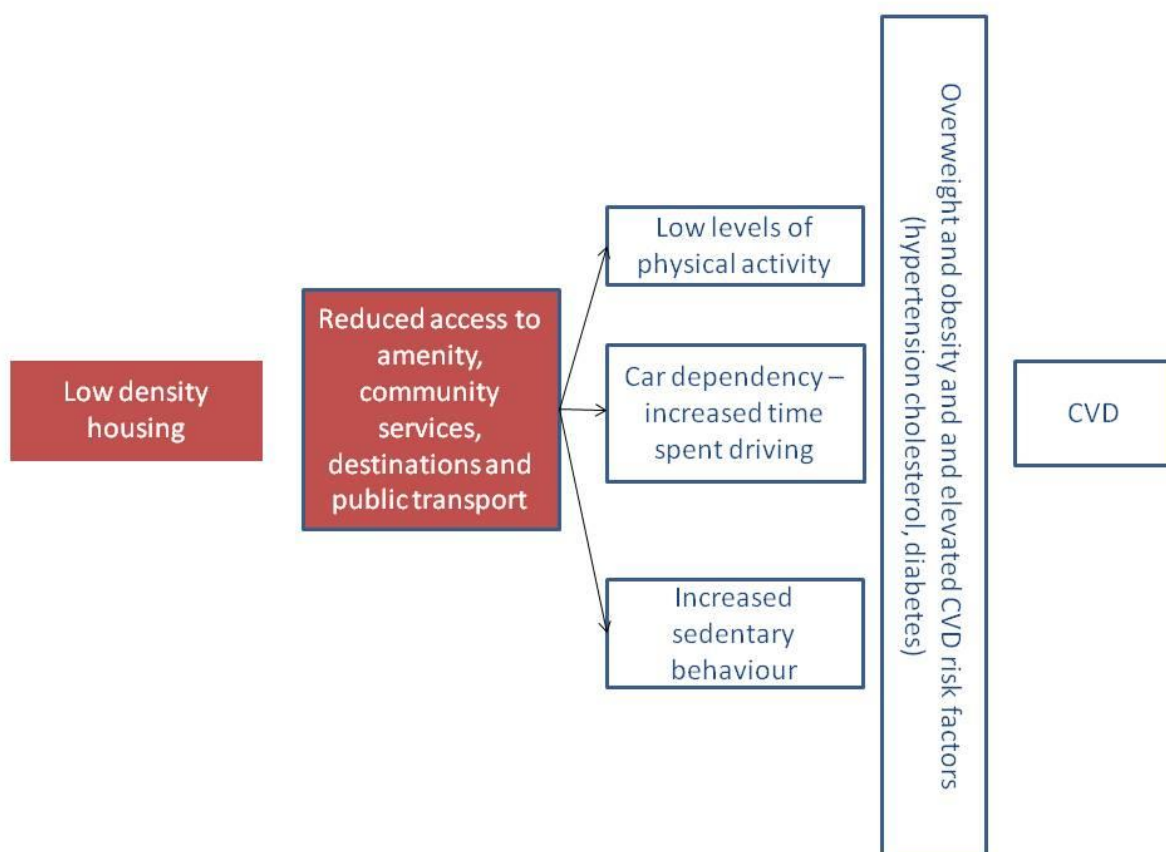
density, public transport and local shops and services are not viable, nor is there sufficient population to create vibrant local communities. The diversity of housing available in local neighbourhoods also impacts the neighbourhood's density.

Thus, the two major questions driving this report, are whether low density development is impacting the health and wellbeing of residents and if so, whether there is an optimal level of density that could be recommended.

Hence, the main purpose of this report was to explore what, if any, health impacts are associated with continuing to build low density detached housing on the urban fringe and whether there is an optimal level of density that could be recommended? It was commissioned by the Victorian Division of the Heart Foundation specifically to examine the impact of low density housing development on cardiovascular health outcomes and risk factors. It seeks to answer a number of key questions:

1. What is the relationship between low density development and physical activity levels (including walking, cycling and access to public transport)?
2. What is the relationship between low density development and physical inactivity (or sedentary behaviour) and cardiovascular disease (CVD) health outcomes?
3. What are unintended health and physical activity consequences of low density development?
4. What is the threshold at which the health consequences associated with lower density housing are minimised and /or avoided (i.e., what is optimal)?

In seeking to understand these relationships, the conceptual model in Figure 1.1 drove this review:



**Figure 1.1** Hypothesized relationships between low density housing and health outcomes

## 2. Methods

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This project involved a rapid review of evidence published in the last five years only. It focussed on the association between low density developments (including urban sprawl and greenfield developments) and physical activity levels and sedentary behaviour, with a major emphasis on the environmental attributes that encourage active forms of transportation, sedentary behaviour and car dependency. The Heart Foundation asked the reviewers to provide guidance about the optimal density levels required to create 'healthy' communities that support physical activity and produce cardiovascular health benefits. Thus, in addition to the main review, we undertook a review of urban and transport planning journals and books to attempt to answer this question.

For the main review, sixty-nine papers were identified through searches of four electronic databases: Web of Knowledge (including Web of Science and Medline), PubMed, Scopus and Cinus-Plus. Limits on search terms included English language and published in the last 5 years, with all searches conducted in November 2013. Five separate searches were conducted within each database. The following search terms were used:

### Search 1:

- ("urban sprawl" OR "dwelling density" OR "residential density" OR "low density housing" OR "low density settlement" OR "greenfield development" OR "growth areas" OR "urban fringe" OR "urban growth boundaries") AND
- ("physical activity" OR "physical inactivity" OR walking OR cycling OR "public transport" OR "active transport" OR "cardiovascular disease" OR "independent mobility" OR overweight OR obesity OR "car dependence" OR driving OR sedentary OR "sitting time" OR "screen time" OR screentime OR television OR "TV viewing time" OR "sedentary time" OR "sedentary behaviour" OR "sedentary behavior" OR "time spent in cars" OR "time spent driving" OR "time spent in vehicle" OR tv OR inequity OR disadvantage OR "socioeconomic status")

### Search 2:

- (shop\* OR retail OR destination\* OR "mixed use" OR connectivity OR walkability) AND
- ("physical activity" OR "physical inactivity" OR walking OR cycling OR "public transport" OR "active transport" OR "cardiovascular disease" OR "independent



mobility" OR overweight OR obesity OR "car dependence" OR driving OR sedentary OR "sitting time" OR "screen time" OR screentime OR television OR "TV viewing time" OR "sedentary time" OR "sedentary behaviour" OR "sedentary behavior" OR "time spent in cars" OR "time spent driving" OR "time spent in vehicle" OR tv)

Search 3:

- ("urban sprawl" OR "dwelling density" OR "residential density" OR "low density housing" OR "low density settlement" OR "greenfield development" OR "greenfield development" OR "growth areas" OR "urban fringe" OR "urban growth boundaries") AND
- ("open space" OR services OR destinations OR shops OR retail OR "mixed use" OR "affordable living" OR thresholds OR employment OR retirement OR connectivity)

Search 4:

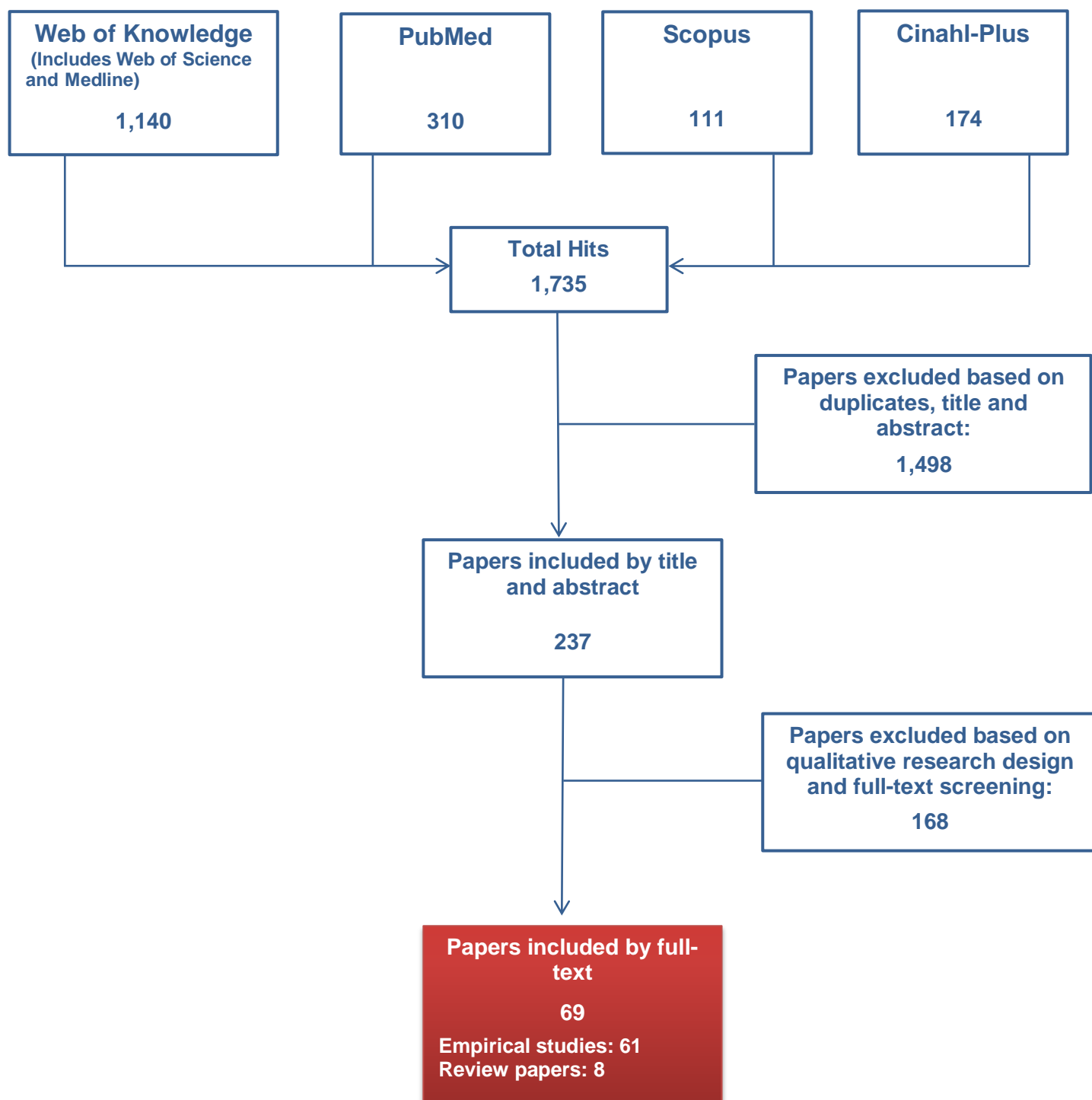
- ("low density housing" OR "low density settlement" OR "urban sprawl") AND
- (adult\* OR children OR adolescent\* OR "older adult\*" OR elderly OR family)

Search 5:

- "Flexible suburb"

In addition to being restricted to papers in English language and published in the last five years, Search 2 was also limited to review papers.

The total number of hits was 1,735. After excluding duplicates and making exclusions based on title and abstract, 237 papers remained. Of the 69 papers included in the review, 61 were empirical papers and 8 were review papers (Figure 2.1). The review papers were summarised based on the positive, negative or neutral associations reported between physical environmental variables and our chosen outcomes by the different population sub-groups covered (i.e., children, adolescents, adults and older adults). Of the 69 papers included in the main review, 61 were empirical papers and 8 were review papers (Figure 2.1). Additional eligible papers were added from each reviewers own endnote libraries.



**Figure 2.1** Search strategy and exclusions for final selection of papers in main review

This report addresses each of the key questions relevant to the major aims of this review, before making concluding comments. In each section, we seek to summarise the evidence, and give a sense of the quality of the evidence-base supporting the conclusions drawn.

### **3. An overview of impact of low density housing development from a health perspective**

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Over the past few decades, sprawled low density suburban development (often referred to as 'conventional' development) has become standard in North American and Australian cities, particularly on the urban fringe. These often consist of uniform residential dwellings situated on large lots, along curvilinear street patterns, with few (if any) destinations to walk and are instead served by large car-oriented shopping complexes such as 'big-box' shopping centres, and retail and office parks. As such all work and leisure activities are usually undertaken outside the neighbourhood. What ultimately distinguishes 'low density suburban development' from alternative development patterns is the poor accessibility of related land uses to one another <sup>12</sup>. The increased distances combined with the indirect routes associated with the street network patterns, make it impractical for residents to walk or cycle to destinations required for daily living as part of their daily routine <sup>13, 14</sup>. Additionally, road construction standards focused on moving cars long distances at high speeds at the expense of pedestrian and cycling infrastructure <sup>14, 15</sup> have resulted in busy high-speed roads that are unpleasant or unsafe for walking or cycling. Moreover, low density housing developments make frequent public transport service provision unviable, further fuelling automobile dependency <sup>16, 17</sup>. Sprawled low density housing development contrasts with more traditional forms of development characterized by higher population densities, connected grid pattern street networks, and a mix of destinations integrated within close proximity of a variety of residential dwelling types <sup>15</sup>.

In terms of walking behaviours, higher population densities provide a reliable customer base for local businesses and public transport, making shops and services economically viable and result in a greater variety of destinations within a more compact area (e.g., traditional neighbourhoods). This affects walking behaviour by increasing the proximity of destinations and thereby reducing the need to travel by car – features that are severely lacking in the low density suburban developments that are an outcome of current planning practices.

Thus, the question of density and its impact on physical activity patterns and cardiovascular disease risk factors cannot be considered in isolation of the neighbourhood characteristics to which it relates. That is, higher density housing goes hand-in-hand with increased land use mix and other urban form characteristics that encourage walking, cycling and physical activity. Density makes the provision of local destinations and public transport services that encourage active modes of travel, viable and accessible. In addition, higher densities

generally result in the creation of more compact neighbourhoods, thereby decreasing the distances to and in-between mixed land uses and destinations.

## 4. What is the direct relationship between low density development and physical activity levels?

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Overall, 25 published articles met the criteria for inclusion. Fifteen of the studies examined relationships between objective measures of density and physical activity outcomes. The remaining ten studies examined perceived or self-report measures of density.

### **Objective measures of density and physical activity**

Of the 16 studies using objective measures of density, two were conducted in Australia, one in New Zealand, eight from the USA and Canada, two in Europe and one in Japan, China and Ireland. Eleven of these studies were of adults, two of older adults, one of children (9-10 years of age), one of adolescents (13-15 years of age) and one was mixed. A number of different physical activity outcomes were assessed.

**There is consistent cross-sectional evidence that residential density is positively associated with walking:** Seven of the eight studies with a self-reported walking outcome reported positive associations with residential density – indicating that increases in residential density were associated with increases in walking behaviour. For example, a study of six US cities <sup>18</sup> found that the density variable was most consistently related to walking across all six cities. Higher population densities (measured as numbers of people/hectare) were associated with higher odds of walking to places and walking for exercise in adults and older adults. Another study <sup>19</sup> examined cross-sectional associations between urban sprawl and physical activity (self-reported) among men throughout the U.S. The “sprawl index” considered gross population density, percentage living at low and at high densities, county population per square mile of urban land, average block size, and percentage of blocks 500 feet or smaller on a side (a traditional block size). Living in less sprawled areas (i.e., higher densities) was significantly associated with more walking - participants living in the least sprawled areas (i.e., higher density areas) were more likely to meet physical activity recommendations through walking.

Three studies examined associations between density and cycling in adults and children. The first study – a longitudinal study of participants in Australia, <sup>20</sup>, found that the uptake of transport-related cycling after relocating to a new neighbourhood was determined, in part, by an increase in objective residential density. This is consistent with a large study in the US <sup>21</sup> that conducted analyses using pooled data from two individual-level national surveys (of a

total of 220,633 people) examining the effects of variations in levels of urban sprawl and fuel pricing on cycling as a form of physical activity. The results indicated that the prevalence of cycling was higher in less sprawling areas. Living in a metropolitan area with a lower degree of urban sprawl increased the probability of cycling by men and women in the past month by 3.4-4.4 percentage points and 1.6-2.1 percentage points from the means, respectively.

However, there may be differences according to age. Perhaps not surprisingly, the third study found that children living in neighbourhoods with higher residential density had lower cycling skill scores than children living in lower residential neighbourhoods. The study by Ducheyne<sup>22</sup> investigated the relative contribution of individual and physical environmental correlates in explaining variance in children's cycling skills. Regression of cycling skills on residential density revealed that 12% of the variance in cycling skills was explained by residential density ( $\beta = -0.37$ ). Furthermore, residential density was the only environmental factor that correlated significantly with cycling skills. Since residential density is an important component of the neighbourhood walkability measure it seems that for children, living in low walkable neighbourhoods was associated with better cycling skills. This may be in part related to exposure to traffic, a major factor determining whether or not parents allow their children to walk or cycle locally. A study by Trapp and colleagues<sup>23</sup> in Perth Western Australia, found that boys were more likely to cycle to school than girls. However, neighbourhood design around schools affected whether or not they cycled. Specifically, boys attending schools in neighbourhoods with high street connectivity and low traffic were 5.58 times more likely to cycle than other boys, and for each kilometre boys lived from school the odds of cycling reduced by 30%. Importantly, irrespective of gender, cycling to school was significantly associated with parental confidence in their child's cycling ability and this was affected by their perception of neighbourhood safety. Thus, higher residential density may well be a marker of areas with more traffic and strangers, which may account for the findings in children by Ducheyne et al.<sup>22</sup>. This is likely to be age-specific. For example, a study of Irish secondary students found those in higher density areas were more likely to walk to school, although there was no such association for primary school students<sup>24</sup>.

Six of the studies reviewed examined the association between residential density and physical activity or an exercise outcome. Once again, the findings suggest a positive association between residential density and physical activity. Three studies reported positive associations between higher residential densities and physical activity<sup>25-27</sup> and leisure-time sports activity<sup>28</sup>. A study in New Zealand<sup>27</sup> found that a one standard deviation increase in dwelling density was associated with both self-reported transport and leisure walking physical activity (any vs none). This study also included an objective measure of physical

activity, finding one standard deviation increases in residential density to be associated with a 7% increase in accelerometer counts. Another study <sup>29</sup> used a measure of urban sprawl rather than density. It found a significant negative association between urban sprawl and daily time spent on family-engaged physical activity. Conversely, one US study found *no* associations between density and self-reported exercise outcomes in adults <sup>30</sup>. However, in this study the questions about 'exercise' were crude and the type of 'exercise' behaviour unspecified (i.e., 'work out' or simply 'exercise'). Yet there was also evidence to the contrary. A Chinese study reported negative associations between density and time spent in recreational physical activity in adolescents.<sup>31</sup> In this study the densities were relatively high by Australian and North American standards, with the medium residential density being 7,862 persons/km<sup>2</sup> (or 79 persons/hectare), and the range at 36-127 persons/hectare. The extent to which this result is due to level of density (with increased numbers of strangers in areas of higher density), or cultural factors is not clear.

Thus, in summary, most of the studies examining the relationship between housing or population density and different physical activity outcomes have found a positive relationship i.e., Higher density development is generally associated with higher levels of physical activity, particularly walking. Whilst a large number of studies have now examined 'density,' its definition and measurement varies across studies. **Nevertheless, the evidence appears to consistently indicate that those living in higher density neighbourhoods undertake more walking and physical activity than those living in lower density neighbourhoods.**

### **Perceptions of density and physical activity**

Of the 16 studies examining participant's perceptions of density, four were conducted in Europe, three in the USA, two in Japan, one in China and one in Nigeria. Eleven of the studies focussed on adult populations, three studies on adolescent populations and one on children's active travel behaviour (based on parent reports).

Overall, positive associations were found between adults' perceptions of higher densities and physical activity outcomes. Five studies from Japan, Nigeria, Germany and the US found positive associations between adult perceptions of (higher) density and walking for transport. Conversely, in a study of 11 countries <sup>32</sup> just one (Norway) found a positive association between participant perceptions of density and physical activity. However, the lack of findings in this study could be due to the crude proxy measure of density used (i.e., participants' perceptions of the main housing type present – detached family housing was used to represent low residential density whilst all other housing types were coded as high



residential density). In contrast, a US study of Hispanic adults used a more specific measure and found an association i.e., perceiving they lived in denser residential environments with access to shops and services was associated with increased odds of walking or cycling to work <sup>33</sup>.

Most studies of perceptions have not examined different types of physical activity behaviours. Associations between perceived density and leisure related physical activity appear to be mixed – a Chinese study <sup>34</sup> found that perceptions of higher density were associated with increased recreational or leisure time physical activity in middle-aged adults. However, a German study of adults <sup>35</sup> found negative associations between perceptions of density and levels of moderate-vigorous physical activity.

Most studies have not examined gender differences. However, one study <sup>36</sup> revealed that for female participants' perceptions of increased density were associated with decreased walking behaviour. Similarly, few studies considered perceptions of younger people. Three studies <sup>37-39</sup> identified positive associations between perceptions of higher density and adolescents' active transport to school. Both the role of gender and age warrant further investigation.

**In summary, evidence examining the direct relationship between perceptions of residential density and physical activity outcomes is mixed and firm conclusions cannot be drawn.** Furthermore, the inclusion of measures of perceived density in studies has both positive and negative implications for the interpretation of findings. Perceived density relates to how dense people perceive their neighbourhood to be, however this can often be an emotive urban design characteristic. From a practical perspective higher residential densities are required to create a critical mass of people to support the provision of local services and public transport. Additionally, having more people in an area increases the number of people seen out walking, which in turn may make people feel safer. However, Rapoport <sup>40</sup> argues that perceptions of residential density often measure people's perceptions of the problems associated with density (i.e., the development as ugly and un-landscaped, with increased traffic and parking problems; or as having more strangers and different kinds of residents). This may adversely affect how people feel about their neighbourhood and therefore their confidence to walk. Similarly, if higher density communities are associated with increased traffic and more strangers, this may affect parent perceptions of its suitability to allow children to walk or cycle <sup>23</sup>.

## 5. What is the direct relationship between low density development and physical inactivity (or sedentary behaviour)?

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‘Sedentary behaviour’ encompasses a range of non-exercise activities that involve sitting or lying, where most major muscle groups are under relaxation, such as television viewing, screen based entertainment, occupational sitting and vehicle travel <sup>41</sup>. Increasingly, sedentary behaviour is being recognised as an independent risk factor for a range of chronic diseases, with studies associating sedentary behaviours with obesity, diabetes, cardiovascular disease, metabolic syndrome, poorer mental health and total mortality <sup>42-44</sup>. Further, the association between sedentary behaviours and poorer health appear to persist even among those who meet recommended levels of physical activity <sup>45</sup>.

Just two published articles meeting the inclusion criteria examined a sedentary time outcome. While there was no association between the perception of living in a higher density environment and leisure-time screen use for Hispanic adults in the USA <sup>33</sup>, a study of Australian adults (aged 20-65 years) found lower residential density was associated with prolonged sitting in cars <sup>46</sup>. This is likely to be related to distance from work, shops and services, which increases the time spent driving and commuting between home and work.

Six studies examined the association between residential density and other car dependency outcomes, such as car ownership rates, private vehicle commutes, and the age at which young people start driving. Overall, findings were somewhat mixed, but suggested there is a greater reliance on cars in lower density environments. For instance, a US study revealed that young adults (16-19 years) living in lower density environments tended to initiate driving at a younger age than their counterparts in denser environments <sup>47</sup> and, in an Irish study, households in low density environments were more likely to have multiple cars, and those with access to multiple cars were less likely to walk, cycle or use public transport <sup>48</sup>. Indeed, another US study with a large sample highlighted that adults living in lower density neighbourhoods needed to drive 4.8% more, and use 5.5% more fuel than their counterparts in a higher density neighbourhood <sup>49</sup>.

However, there were also some conflicting findings from the studies focussing on commute times. For example, in a study of European adults, higher residential densities were associated with longer trip durations. The authors suggested that this finding may relate to

the traffic congestion that is often a by-product of higher density environments,<sup>50</sup> highlighting the important interrelationship between land use and transport planning. Similarly, a US study highlighted an association between density and commute times, whereby lower densities, more connectedness and better accessibility were associated with short private vehicle commute distances<sup>51</sup>. Ultimately the location of a neighbourhood, residential densities and access to public transport, will contribute to car dependence - or its flip side – public transport use. For example, Nagengast et al.<sup>52</sup>, identified that US residents in brownfield sites, which are typically closer to the city centre, tended to have higher public transport use than those in greenfield sites. However, these areas are also more likely to have higher densities and better public transport access, in addition to their closer proximity to the city.

Another four studies focussed on a combination of physical activity and car dependency outcomes, such as travel mode choice. This literature appears somewhat consistent, with most studies identifying an association between higher densities and the likelihood of public transport use or active transport (i.e., walking or cycling). For instance, in Greece, residential density and distance from the city centre were direct influences on the transport mode choice<sup>53</sup>. Similarly, a study set in China reported that the likelihood of adults commuting by public transport were 2.8 times higher in areas with higher populations density (albeit not statistically significant)<sup>54</sup>.

In summary, while these studies were diverse in terms of the setting, population and outcome, there appears to be relatively consistent evidence of an association between residential density and transport mode choice, with higher residential densities positively associated with active transport modes, and (in general) negatively associated with car dependency outcomes. This suggests that living in lower density developments is likely to result in residents having greater car dependency, with longer commute times and using fewer active modes of transport. However, in the last five years there is insufficient evidence to conclude that lower density development results in more time in sedentary leisure-time pursuits and this warrants further exploration.

## 6. What is the direct relationship between low density development and CVD health outcomes and obesity?

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### CVD health outcomes

Overall, only two published studies met the criteria for inclusion in this review, one US study which examined the relationship between urban sprawl and coronary heart disease (CHD) in women <sup>55</sup>; and a Taiwanese study examining the association between access to facilities for habitual physical activity and metabolic syndrome. No studies focussed specifically on CVD *per se*. The US study considered four measures of urban compactness: residential density, mixed land use, street connectivity and centredness. However, residential density had the most notable independent effect on CHD after full adjustment for a range of socio-demographic variables (including education and income); family history of myocardial infarction, dietary factors and a range of neighbourhood socioeconomic factors. There was an inverse relationship between residential density and CHD: Women living in denser communities had a significantly lower risk for any CHD event (HR=0.94) and CHD death (HR=0.90). In contrast, a Taiwanese study <sup>56</sup> focussed on facility density, rather than population or housing density. It found that a greater availability of free facilities for habitual physical activity was associated with a lower risk of metabolic syndrome amongst its residents.

One further study, examined the association between walkability and cardiometabolic risk factors in Perth, Western Australia <sup>57</sup>. Density was included within the index of walkability but not alone, hence it did not meet the criteria for inclusion. Nevertheless, this study found a protective association between neighbourhood walkability and obesity and type-2 diabetes mellitus, with the latter particularly evident in men. However, no association was found between walkability and hypertension or hypercholesterolaemia.

**In summary, evidence examining the direct relationship between residential density and cardiovascular outcomes is sparse and firm conclusions cannot be drawn.** Only two available studies met the criteria for inclusion and one involved women only. There appears to be some preliminary evidence that higher residential density development is associated with a reduced risk of CHD independent of individual and area-level measures of socioeconomic status. The mechanism through which this occurs is likely to be due to the impact of urban design on CHD risk factors such as physical activity, obesity and diabetes II. Similarly there is preliminary evidence, that areas with a higher density of facilities used for

habitual physical activity may reduce the risk of metabolic syndrome. However, this is based on one study only. **The evidence-base is limited, and findings are suggestive rather than conclusive. Further research is required in this area.**

### **Overweight and obesity**

Overall, nine published articles met the criteria for inclusion, six undertaken in the USA, one in Finland, one in Nigeria and one in China. Of these studies, three involved adults, two children through to adults, one adolescents, two children through to early adults (i.e., 3-18 years) and one of adults over 50 years. Only one study was longitudinal and examined changes in body mass index over two years.

Of the six cross sectional studies involving adults or older adults, there was a consistent negative relationship between density and weight status. Irrespective of whether density was measured objectively, or subjectively<sup>58</sup> those living in lower density neighbourhoods had a higher weight status than those living in higher density neighbourhoods. Two studies involved adolescents and another involved children through to young adults (5-18 years). These studies had conflicting results. For example, one study of Chinese adolescents found a significant positive relationship between density and overweight<sup>59</sup>. In another study involving children through to early adulthood,<sup>60</sup> a consistent association was found in older children and young adults, with low density development associated with higher BMI irrespective of whether density was measured as 'county sprawl' or population density. However, in younger children neither measure of density was associated with weight status.

One further study of youth aged 3-16 years involved longitudinal data. It examined whether living in greener neighbourhoods was significantly associated with a change in BMI over time after adjustment for family income, ethnicity and health insurance type, and irrespective of residential density<sup>61</sup>. It found that regardless of the level of residential density, higher greenness was significantly associated with lower BMI at follow-up. However, higher residential density *per se* was not associated with changes in BMI.

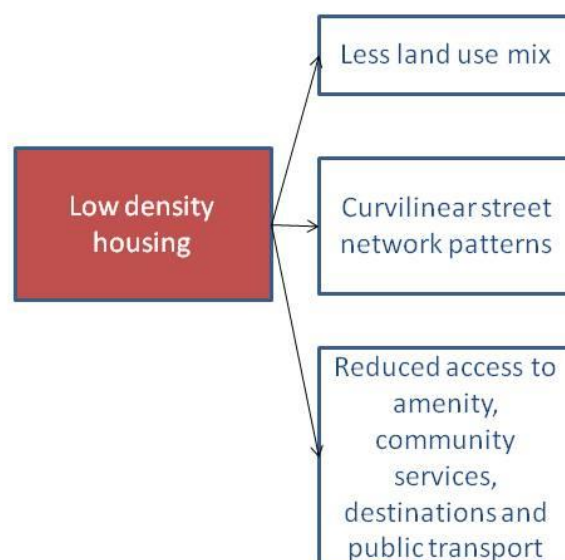
**In summary, there appears to be consistent cross sectional evidence that living in lower density housing is positively associated with increased overweight and obesity in adults and adolescents, but the relationship with weight status in younger children is less clear.** It is likely that living in lower density developments for adults and independently mobile adolescents may restrict walking, and this explains the findings observed. However, for younger children, urban sprawl may have less impact on their

physical activity behaviours: indeed there is some evidence that younger children are permitted to play on the streets in *cul de sacs* and this may explain the patterns observed <sup>62</sup>. The finding that residential density was positively associated with overweight in urban Chinese adolescents is consistent with earlier Portuguese research which found that girls (although not boys) living in high rise development were more likely to be obese compared with those living in lower density housing.<sup>63</sup> It may be that in high rise developments the physical activity patterns of younger children and girls' are constrained due to parental concerns about safety <sup>64</sup>. This suggests that there may thresholds for density, beyond which the benefits of higher density development are compromised <sup>63</sup>.

## 7. What is the indirect relationship between low density development and physical activity, sedentary behaviour and CVD outcomes?

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This section examines the indirect associations between low density housing developments and physical activity, sedentary behaviour and CVD outcomes, through the impact of dwelling density on urban form attributes that encourage local walking. It involved a review of review papers. Figure 7.1 depicts the association between low density development and the urban form attributes frequently associated with active transport behaviours.



**Figure 7.1** The association between low density housing and neighbourhood characteristics found to be associated with lower levels of walking, cycling and public transport use

Eight review papers investigating associations between neighbourhood design characteristics associated with low density development and health outcomes were published in the past five years and were eligible for inclusion. Five different design characteristics were identified from the papers: 1) mixed land use; 2) walkability; 3) connectivity; 4) access to destinations (count, proximity, presence); and 5) access to public

transport. Consistent with Figure 7.1 above, our premise for inclusion of these characteristics is that low density neighbourhoods would be expected to perform poorly on these characteristics compared with higher density areas. Specifically, in terms of walking and active transportation:

- Increased connectivity reduces the distances to destinations and provides a range of routes, increasing the likelihood of walking between locations.
- Land use patterns refer to the spatial distribution and mix of destinations required for all aspects of daily life and recreation (e.g., shops, work, schools, and public open space). Transport theories hypothesize that walking is more likely when a variety of proximate destinations, transit stops and areas of public open space are present (i.e., mixed land uses), as these provide meaningful and convenient opportunities to walk<sup>15</sup>.
- Proximity to public bus and rail stops have also been positively associated with active transportation and walking. As most public transport trips begin or end with walking it provides important opportunities for walking to or from the stop.

Active Living researchers have attempted to combine the environmental components that help to predict transport-related walking. The most commonly applied measure has been the walkability index<sup>65</sup>, which measures the presence of multiple built environmental features by combining scores for variables that represent connectivity, density and land use mix.

Three reviews<sup>66-68</sup> have examined the influence of the built environment on physical activity of adults. Land use mix, street connectivity and population density and overall neighbourhood design have been identified as important correlates of various physical activity behaviours<sup>66</sup> in studies from North America, Australia and a number of European countries. These reviews presented convincing evidence of strong positive relationships with walking and cycling for transport with increased walkability and access to shops/services/work. The review of European-based studies also found evidence for a positive relationship between the degree of urbanization and total walking – people living in more urbanized areas walked more than people living in less urbanised regions.

A systematic review of studies examining the influence of the built environment on physical activity of adults in rural settings<sup>69</sup> demonstrated significant positive associations of aesthetics, safety from crime or traffic, access to recreational facilities, presence of trails and parks, access to walkable destinations with physical activity.



The evidence for children and young people is less consistent. Two reviews focussed on associations between environmental attributes and physical activity among children and adolescents <sup>70, 71</sup>. Greater land use mix, destinations and residential density were all positively associated with physical activity as was access to recreation facilities and public open space. Distance to school was consistently found to be negatively associated with active school transport whilst pedestrian safety structures were also positively associated with several physical activity outcomes, as was the presence of walking and cycling facilities and lower traffic speeds and volumes.

One of the review papers examined the quantitative research examining built environmental variables associated with obesity in children and adolescents <sup>72</sup>. Housing density was found to be unrelated to BMI in children and land use mix was unrelated to BMI in children and adolescents. One reported study examining walkability found it to be associated with BMI in girls but not boys. Moreover, walkability was unrelated to BMI in adolescents. The lack of associations with these features may be due, in part, to a lack of independent mobility in these young people. However, increased access to physical activity and recreation destinations or facilities has consistently been found to be associated with lower levels of obesity in adolescents.

In summary, there is consistent and convincing evidence of the indirect associations of residential density, through its role on the walkability of an area and the associated urban form, on physical activity of adults and children.

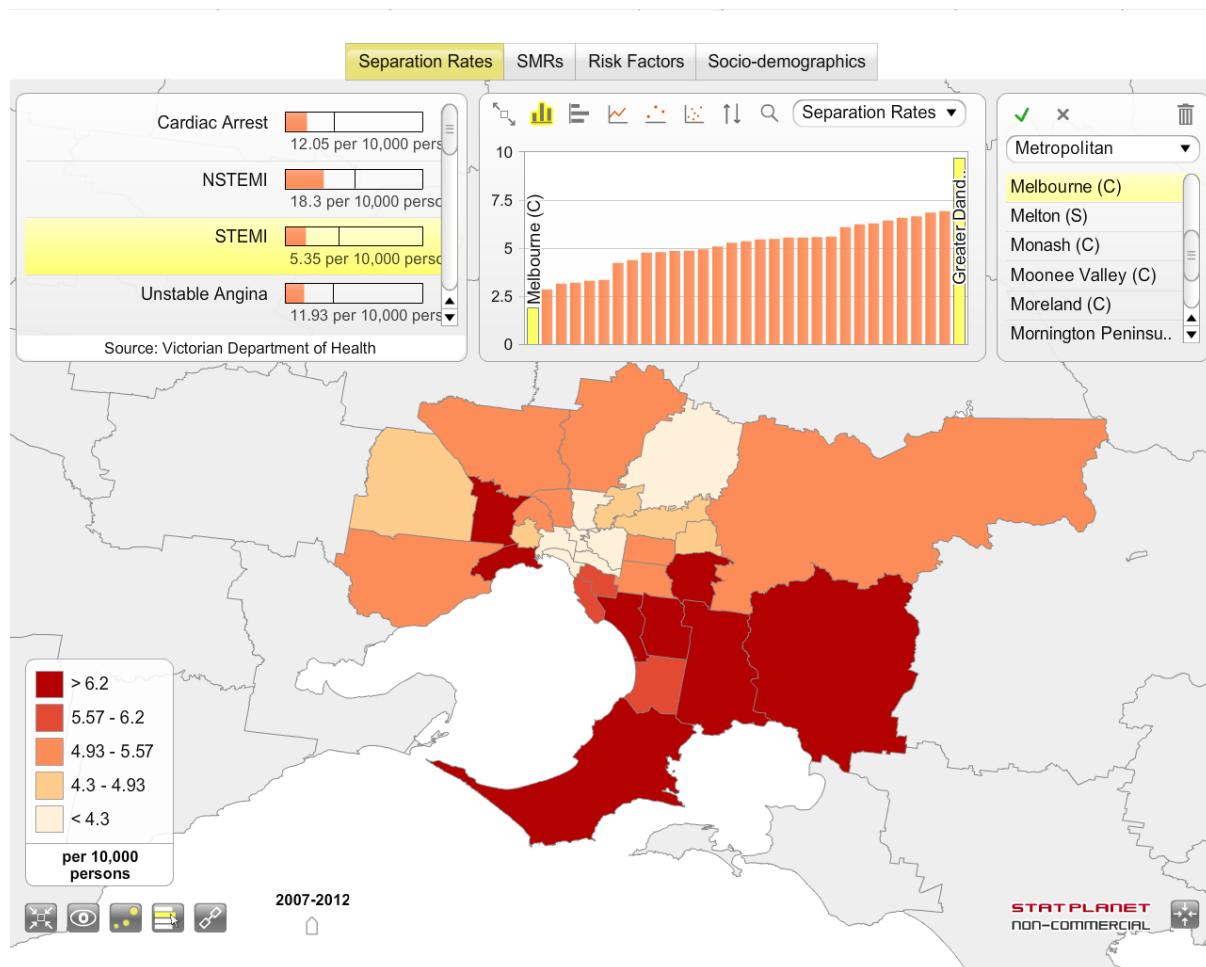
## 8. What are the unintended outcomes of low density development?

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This review indicates that low density single use development appears to have number of unintended consequences with negative consequences for cardiovascular health outcomes: adult residents living in these developments are less likely to walk and to use public transport, will spend more time driving, and along with adolescents, are more likely to be overweight or obese. Although beyond the scope of this report, an earlier study (admittedly prior to the review period) found that each additional hour/day spent in a car was associated with a 6% increase in the likelihood of obesity <sup>43</sup>, meaning those living on the urban fringe, with poorer access to proximate shops, services or employment are increasingly vulnerable. Further, there are other unintended consequences that stem from a reliance on private cars for travel, including the risks of crash related injuries, particularly among young people. <sup>47</sup>

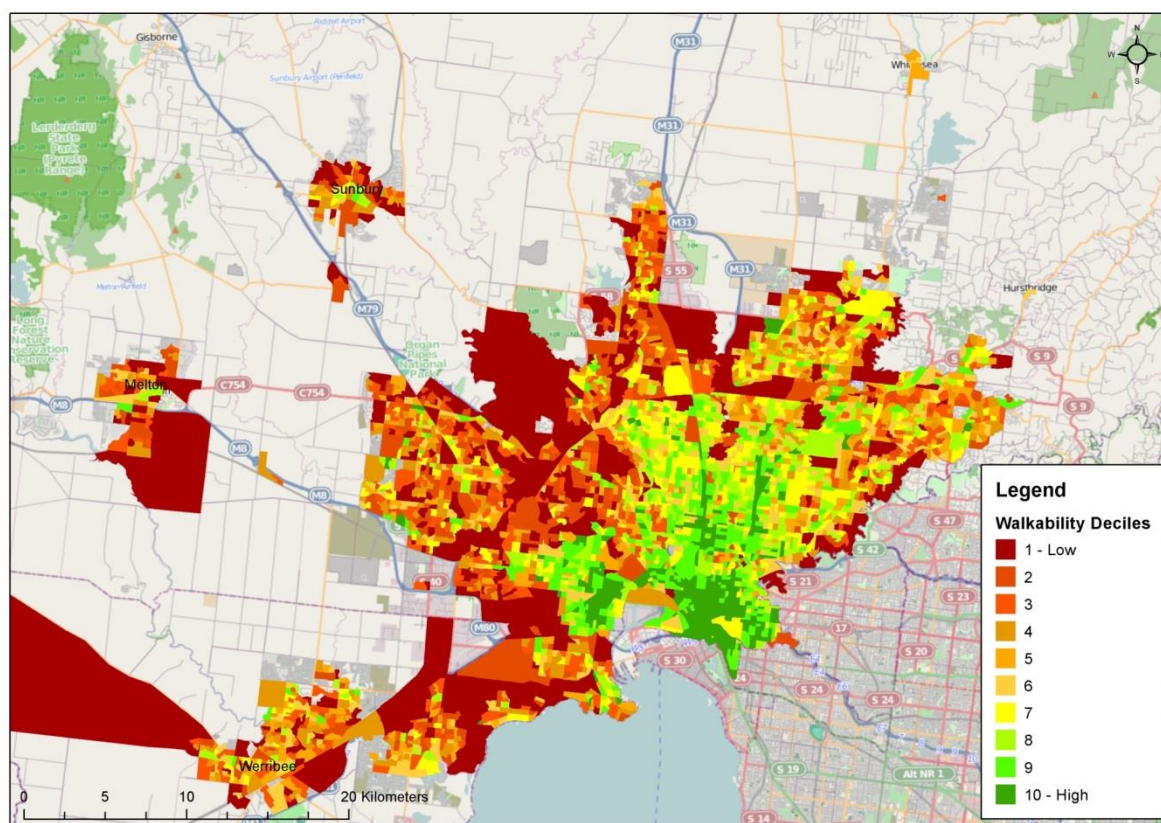
At this stage, the direct effect of low density development on cardiovascular health outcomes is unclear. However, it is important to acknowledge that cardiovascular outcomes are spatially patterned. The Heart Foundation itself has produced maps of hospital admissions due to Heart Attack across Metropolitan Melbourne. These show that heart disease is spatially distributed. For example, as shown in Figure 8.1 residents of outer and middle suburbs of Melbourne, have poorer cardiovascular outcomes than those living in inner suburbs of Melbourne. The extent to which these disease patterns are contextual (i.e., related to the built environment) or compositional (i.e., related to the type of people who live in those areas) – or a combination of the two – cannot be determined from these maps. Although they usefully describe the problem, they cannot be used to determine what is causing the problem.

However, physical inactivity - including insufficient walking – is an independent risk factor for heart disease and is correlated with a number of other cardiovascular risk factors (i.e., hypertension, cholesterol, weight status). As demonstrated in this review, the likelihood of engaging in physical activity – particularly walking – appears to be associated with the built environment. If outer and middle suburban areas discourage walking, then this is one factor contributing to poor cardiovascular disease outcomes.



**Figure 8.1** Hospital Admissions for Heart Attack in Metropolitan Melbourne, 2007-08 to 2011-12 (Source: Personal correspondence Kellie-Anne Jolley, Heart Foundation).

With funding provided from the Australian Urban Research Infrastructure Network, University of Melbourne's Place, Health and Liveability program at the McCaughey VicHealth Centre for Community Wellbeing, developed a walkability map for Melbourne's North-West Region (Figure 8.2).<sup>73</sup> This shows that many outer suburban areas of Melbourne are considerably less walkable than other areas i.e., they have lower residential density, less mixed use development and the streets are less connected. While many middle suburban areas are also low or only moderately walkable, it is notable that middle suburban areas located along the train routes are considerably more walkable than other middle suburban areas. Whether this has cardiovascular benefit, remains to be explored in future research.

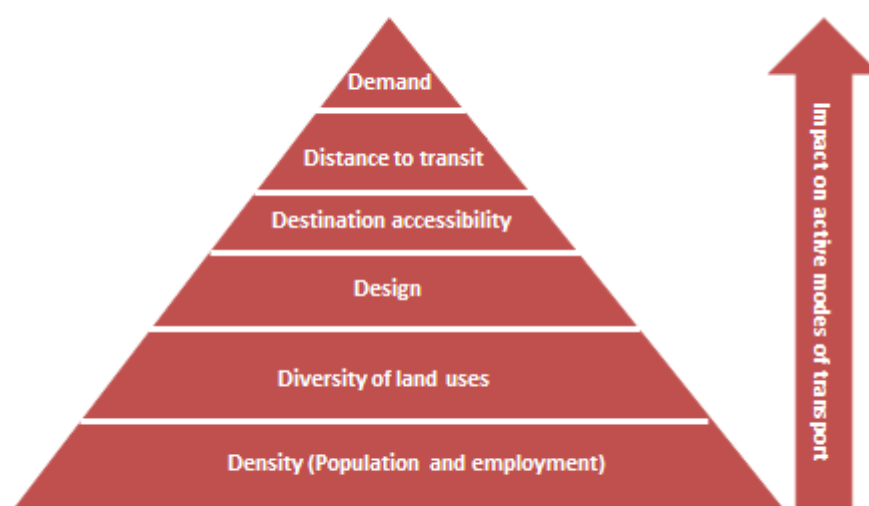


**Figure 8.2** The walkability of the North-West Region of Melbourne

As mentioned earlier, while density is critical, urban and transport planners have distilled the essence of land use features required to encourage more walking, cycling and public transport use into the six ‘D’s’,<sup>11</sup> density, diversity, design, distance to transit, destination accessibility and demand management (i.e., the cost and availability of parking). While *density* is a critical feature because it underpins most of the other D’s, the 6D’s have the biggest impact when they work together.<sup>74</sup>

In the transportation literature, land use diversity and population, employment and retail density are consistently shown to be positively associated with walking and cycling for transport.<sup>17</sup> Nevertheless, as Handy (in <sup>17</sup>) observes, it is not density *per se* that increases walking and cycling for transport and transit use, rather density works in combination with other built environment features (local destinations and access to transit) that makes the presence of other essential infrastructure viable.

Additionally, it is not just housing or population density that appears to be important. In analysing factors that decrease motor vehicle dependency and encourage public transport use for example, Newman and Kenworthy<sup>75</sup> found that it is the combination of both population *and* employment density that is important. Indeed, population and employment density are sometimes summed to compute an overall *activity density* per unit area.<sup>11</sup> In Figure 8.3, we show how both population *and* employment density underpin the impact of the other land use features that are associated with increased use of active modes. Without density, it is not possible to have a diversity of land uses, and accessible destinations and transit proximate to people's homes as density makes these other built environment features viable. However, questions remain about whether there is an optimal level of density that enhances physical activity and health.



**Figure 8.3** 6Ds of land use features associated with active modes of transport

In summary, this section found that lower density development is associated with lower levels of walking for transport which is likely to contribute to poorer cardiovascular health outcomes. Importantly, however it concluded that to increase walking, cycling and public transport use density needs to be considered along with the 6 D's: Diversity, design, distance to transit, destination accessibility and demand management.

## 9. What might be a threshold at which the health consequences associated with lower density housing are minimised and/or avoided (i.e., what is an optimal level of density)?

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The potential for evidence to influence the urban design and planning policies is limited unless it can be translated into place-based planning criteria to which urban designers can relate and refer. In terms of criteria around density, specific evidence is needed to inform policy and practice about optimal thresholds of density interventions required to optimise health and wellbeing outcomes. Hence, a specific objective of this report was to review the evidence on what constitutes a ‘minimum’ threshold for density that will optimise health and wellbeing outcomes. This is a vexing question, about which the literature is not clear. The transportation research community has attempted to empirically estimate minimum thresholds for density for reducing vehicle miles travelled (VMT); to reduce motor vehicle dependency; to increase public transport use; and to increase walking. However, in terms of developing ‘standards’ for practice, no clear guidelines are apparent.

The question of optimum densities for city dwellings is not a new question: in the 1960s, visionary urbanist Jane Jacobs, thoughtfully mused that:

‘...proper city dwelling densities are a matter of *performance*. They cannot be based on abstractions about the quantities of land that ideally should be allotted for so-and-so many people (living in some docile, imaginary society). Densities are too low, or too high, when they frustrate city diversity instead of abetting it. We ought to look at densities in much the same way as we look at calories and vitamins. Right amounts are right amounts because of how they perform. And what is right differs in specific instances’....<sup>76</sup>

Hence, if the focus of density recommendations is viewed through a ‘cardiovascular health’ lens, then the priority performance criteria for density would be a minimum level of density that would promote *cardiovascular health and wellbeing* and specifically encourage physical activities such as walking and cycling for transport and recreation. Nevertheless, by using a health lens numerous co-benefits across multiple other sectors would accrue from prioritising levels of density to increase utilitarian walking and cycling and public transport use:

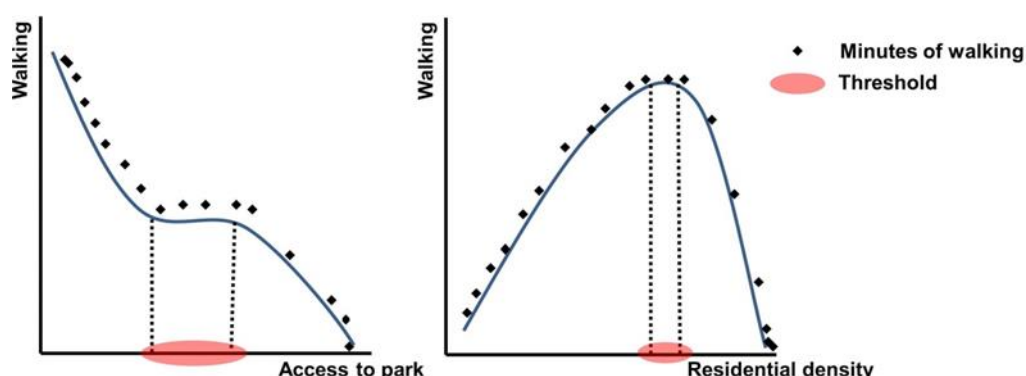
transport and traffic management, environment, sustainability, community development as well as health.<sup>77-79</sup>

The Lincoln Institute of Land Policy has specifically explored the topic of the levels of density required to promote utilitarian walking from a traffic management and sustainability perspective<sup>74</sup>. This was not without challenge. Campoli suggests that while a rule of thumb is readily applied in transit planning for how far the average person is willing to walk (i.e., 450-800 metres), devising a threshold for population density is more difficult because – as Jacobs also observed - ‘it depends’: on the location, on culture and expectations, but also on resources and infrastructure. For example, Hong Kong is very different to suburban Melbourne. Similarly, there are within city differences. Outer Melbourne is different to inner Melbourne.

In attempting to move the agenda forward and explore optimum density thresholds to encourage walking, Campoli began by exploring the area of land that would be traversed if the average person was willing to walk 450-800 metres. ‘Extending a line of (450m) in all directions from a central point creates a pedestrian shed or a walk zone of roughly (50 hectares)’ (p23<sup>74</sup>). Locating more destinations, transit and higher density housing within this walk zone, would ensure there were sufficient numbers of residents and employees to support local businesses and public transport, and that destinations could be reached in less than 10 minutes. However, devising a threshold for population density within a 50 hectare walk zone still depends upon the location: while there appears to be an optimal distance people are willing to walk, as noted earlier there appears to be no optimum level of density that maximizes both ‘urban efficiency and liveability’. Hence, she argues for an optimal *range* of density.

The view that a range of thresholds for built environment attributes is required is shared by Koohsari and colleagues<sup>80</sup>. For example, while research on residential density and physical activity shows that living in low density suburban sprawl is associated with lower levels of walking for transport, the association between density and walking outcomes may not be linear. In other words, the positive impacts of a given built environment attribute on certain health behaviours, may commence and cease at certain thresholds. For example, the levels of walking to a destination (e.g., a park) may sharply decline if the location is beyond 800 metres from home, although people may be willing to continue to walk up to (say) 900m. In this case, 800-900 metres might be applied as the threshold for park allocation in urban design practice. Similarly, there may be an optimal level of residential density to support different types of health outcomes and behaviours, such as walking (see Figure 9.1), beyond

which walking might well begin to decline, particularly for some sub-groups (e.g., older adults and/or children).



**Figure 9.1** Hypothetical diagram showing thresholds that support walking for access to park and residential density <sup>80</sup>

In a previous Heart Foundation report on the impact of higher density housing on health, <sup>63</sup> we concluded that it was preferable to achieve higher density housing using lower rise rather than high development. Moreover, in terms of an upper threshold for higher density development, we recommended that higher density development up to around 3-6 stories was optimal from a health perspective, particularly for lower income households and households with children. This conclusion is broadly consistent with other practice-based views, suggesting that development up to around six stories creates a compact walkable urban form that is walkable, yet retains human scale: which is important in terms of creating a pleasant, convivial, vibrant yet walkable environment<sup>81</sup>. Critically, however, we argued in our earlier report that density should not be viewed in isolation. Successful higher density development irrespective of form, is contingent upon a range of other factors including: the quality and design of the *building*; the *social environment* and building designs and amenities that suited the resident population (e.g., if families are likely to be residents, the provision of amenities and building design to suit children, adolescents and parents); and finally the *physical environment* and the geographic location (i.e., was the higher density development located on heavily trafficked roads and if so, was the building designed to ameliorate environmental stressor exposures?); and the level of utilitarian (e.g., transit, shops and services) and recreational (e.g., public open space, recreational opportunities) amenities present.

In this report, our goal is to make recommendations at the other end of the spectrum. Here, we are attempting to articulate a *lower threshold* for density to optimize cardiovascular health outcomes. In this case, our question is what is the *minimum* level of density that would meet



our performance criteria of optimising cardiovascular health and wellbeing outcomes by encouraging walking and cycling?

Drawing upon the Lincoln Institute's work, Campoli used a case study approach of compact developments that optimize walking outcomes,<sup>74</sup> and concluded that the lower end of the optimum range of densities **begins** at eight dwellings per acre or 20 dwellings per hectare. Notably, this is the same level of density reported in Western Australia by Learnihan and colleagues in Western Australia who observed:

'In a low density and car-dependent city such as Perth, higher levels of transport walking were observed in areas with housing (net) densities of around 20 houses per hectare. Clearly, higher densities would increase the viability of local businesses, and enhance land use diversity which appears to be critical.' p190<sup>82</sup>

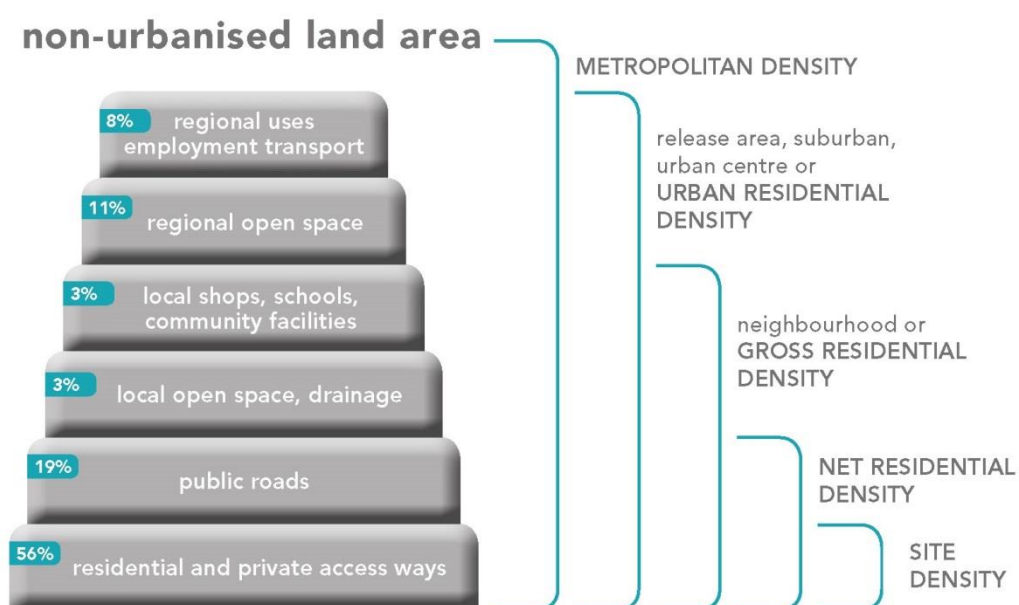
As we have argued earlier in this report, while walking is the key performance indicator of interest to the health sector, to encourage walking we also need to understand minimum levels of density that support public transport and shops and services, as this social infrastructure provides the critical destinations that foster more walking. Surprisingly there have been few empirical studies in the 'urban design' and 'transportation' literature that have specifically investigated the minimum levels of population density required to support public transport and retail<sup>75, 83-85</sup>.

Nevertheless, for the few recommendations available, there appears to be some broad consistency in recommendations. For example, in his classic book entitled "*Community design and the culture of cities: the crossroad and the wall*", Lozano<sup>83</sup>, identified a *net density* of around **30 dwellings per hectare**, as the minimum threshold required to allocate community facilities in close proximity to dwellings. Similarly, after considering the impact of density on 14 residential environment attributes (including the viability of public transport and open space and amenities required) Tonkin<sup>85</sup> recommended an optimum *gross density* range of between 30 to 90 dwellings per hectare. In particular, he suggested that the lower gross density threshold for a viable public transport system was around 30 dwellings per hectare.

This level of recommended density is somewhat higher than the city-wide minimum density thresholds estimated in a study of global cities that fostered public transport use and reduced automobile dependency. Newman and Kenworthy<sup>75</sup> concluded that metropolitan minimum net threshold of urban intensity of approximately 35 **persons** per hectare (equivalent to 13 dwellings per hectare) *plus* 35 **jobs** per hectare were optimum. This latter

threshold value was said to be influenced by a travel-time budget and was said to be sufficient to make local amenities feasible. However, this recommendation was somewhat lower than other recommendations, which may have been influenced by the use of highly aggregated city/metropolitan data used. These data are inappropriate for predicting individual behaviour due to the ecological fallacy<sup>11</sup> i.e., when the average of a population is assumed to have an interpretation in terms of likelihood at the individual level. Moreover, this study reported net rather than gross density and did not report assumptions about dwelling occupancy levels. Nevertheless, the study is important because it highlights the need to combine both dwelling *and* employment density in thresholds required to encourage public transport use. This highlights the challenge of making recommendations about levels of density because of the different approaches to addressing the same question, with studies reporting net density, and others gross density; and some studies considering whole metropolitan areas, and others considering neighbourhood or regional levels.

Thus in making recommendations about levels of density, it is clear that three important issues need to be considered. The first is whether the evidence is based on gross or net density which affects the denominator used to represent the land value or area over which density is being estimated. As shown in Figure 9.2 below,<sup>86</sup> there is around a six percentage point difference in the land area depending upon which denominator is used. The denominator used to estimate net density is based only on land area that covers the land zoned for residential housing (56% of the land area) and the roads (19% of the land area) (i.e., 75% of the land area in total). The denominator for estimating gross density, on the other hand, is based on net density area plus an additional six percentage point area of land allocated for public open space and drainage (3% of land area) and shops, schools and community facilities (3% of land area) (i.e., 81% of the total land area).



**Figure 9.2** Different definitions of residential density by land area (Source: page 9<sup>86</sup>)

In practical terms, this means that density thresholds based on either net or gross density estimates will differ as shown in Table 9.1. If net density is used as the base measure (i.e., the denominator), then net density of 30-35 dwellings per hectare would represent around 28-32 dwellings per hectare based on gross density. However, if *gross density* is used as the base (i.e., gross density of 30-35 dwellings per hectare), then net density would be around **32-38** dwellings per hectare.

**Table 9.1** Minimum levels of density required for public transport depending upon whether 30-35 dwellings/hectare is based on net or gross density

| Baseline denominator density measure | Net density (75% land area) | Gross density (81% land area) |
|--------------------------------------|-----------------------------|-------------------------------|
| Net Density                          | <b>30-35</b>                | 28-32                         |
| Gross Density                        | 32-38                       | <b>30-35</b>                  |

Hence, based on this analysis and the limited evidence available, it would appear that the threshold for gross density to facilitate public transport provision should range from 28-35 dwellings/hectare; and the net density from 30-38 dwellings per hectare. If the mid-point of each range is used, then the optimal **minimum** gross density threshold would be around 32 dwellings per hectare and the **minimum** net density threshold would be around 34 dwellings per hectare.

However, an additional important consideration is the ***number of residents per dwelling***. Most of the evidence on transport thresholds reported is somewhat dated and in at least one report <sup>85</sup> it was made clear that the dwelling density calculation was based on *three persons per dwelling*. In Australia, current average dwelling occupancy levels are around 2.6 *persons per dwelling*. This means that, in Australia, a dwelling density calculation based on three persons per dwelling would over-estimate the average population in an area by around 13.5%. This is important because the number of people in an area determines the viability of public transport, shops and services. For example, in the early 1950s the Australian national occupancy rate was around 4.0 persons per dwelling, 35% higher than it is today at 2.6 persons <sup>87</sup>.

Assuming that all earlier dwelling density estimates in Table 9.1 were all based on *three persons per dwelling*, Table 9.2 adjusts these figures to create dwelling densities based on the current Australian occupancy rates of 2.6 persons per dwelling.

Based on 2.6 persons per dwelling and the limited evidence available, we would recommend the threshold for gross density to facilitate public transport provision should range from 32-40 dwellings/hectare; and the net density from 35-43 dwellings per hectare. If the mid-point of each range is used, then the optimal **minimum** gross density threshold would be around 36 dwellings per hectare and the **minimum** net density threshold would be around 39 dwellings per hectare. However, it should be noted that an appropriate density within the threshold range would likely be context specific.

**Table 9.2** Minimum levels of density required for public transport at occupancy rates of 2.6 dwellings/hectare depending upon whether density calculation is based on net or gross density

| Baseline density measure | Net density (75% land area) | Gross density (81% land area) |
|--------------------------|-----------------------------|-------------------------------|
| Net Density              | <b>35-40</b>                | 32-37                         |
| Gross Density            | 38-43                       | <b>35-40</b>                  |

In summary, based on the limited evidence available, we would recommend that to encourage walking that minimum net dwelling densities of 20 dwellings per hectare or minimum gross dwelling densities of 18 dwellings per hectare be adopted by the Heart Foundation. However, in terms of dwelling densities required for public transport, at Australian occupancy rates of 2.6 persons/dwelling, we would recommend the Heart Foundation adopt an optimal minimum net density threshold of around 35-43 dwellings per hectare and gross density threshold of around 32-40 dwellings per hectare.

## 10. Discussion

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Since WWII, sprawled low density suburban development (often referred to as ‘conventional’ development) has become standard in North American and Australian cities, particularly on the urban fringe<sup>88, 89</sup>. This report examined what, if any, health impacts are associated with continuing to build low density detached housing on the urban fringe and whether there is an optimal level of density that could be recommended.

The report found consistent cross-sectional evidence:

- that those living in lower density neighbourhoods, or who perceived they lived in lower density areas, undertake less walking than those living in higher density neighbourhoods (and vice versa);
- that living in lower density areas is associated with increased overweight and obesity in adults and adolescents (although the relationship with weight status in younger children is less clear); and
- positive associations between people’s perceptions of higher densities and walking and cycling.

There was also relatively consistent cross sectional evidence that:

- residential density is associated with transport mode choice, with higher residential densities positively associated with active transport modes, and (in general) negatively associated with car dependency outcomes. Hence, living in lower density developments is likely to increase car dependency with residents using fewer active modes of transport.

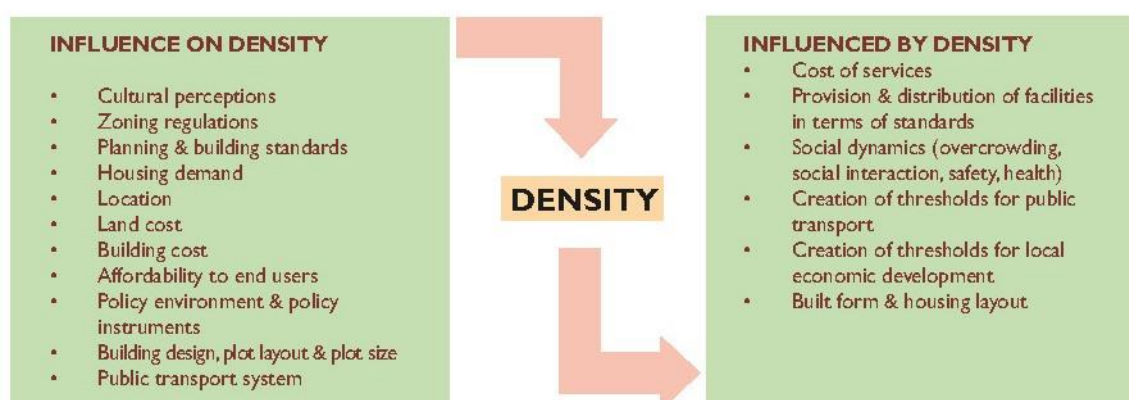
There was insufficient evidence in the last five years to conclude whether or not lower density development results in more time in sedentary leisure-time pursuits, and this warrants further exploration.

Similarly, no firm conclusions could be drawn on the direct relationship between low residential density and cardiovascular because there is dearth of evidence examining this direct relationship. Only two studies met our criteria for inclusion. While both were in the expected direction, there is insufficient high quality evidence to draw firm conclusions at this

stage. Nevertheless, lower residential density development appeared to be associated with an increased risk of CHD independent of individual and area-level measures of socioeconomic status, and living in areas with a higher density of facilities used for habitual physical activity reduced the risk of metabolic syndrome. **However, this is based on two studies only and further research is required in this area.**

There was limited and less consistent evidence on the associations of residential density on children and adolescents physical activity behaviours to allow any firm conclusions to be drawn. Evidence available from the last five years, however, suggests that there may be differences in the impacts of residential density on children's physical activity level according to their age (i.e., children or adolescents). However, the lack of associations with these features may be due, in part, to a lack of independent mobility in these young people, which in itself, has been found to be related to urban design features<sup>90</sup>. However, increased access to physical activity and recreation destinations or facilities has consistently been found to be associated with lower levels of obesity in adolescents.

While there appears to be consistent evidence that increasing suburban density is warranted from a cardiovascular health perspective, building higher density development is not without challenge. Tonkin<sup>85</sup> usefully attempts to summarise the complex range of factors influencing both the building of higher density development but also the implications of density (see Figure 10.1). He argues that building density is related with both the built form (the physical form of a residential area in terms of building height, land coverage and grain of the buildings) and the housing form (the organisation and utilisation of land for buildings, roads, cars pedestrians, open space and landscaping). Moreover, *perceived* density (i.e., the level of density people feel an area has) depends on an individual's cultural background and the nature of the built up area.



**Figure 10.1** Factors influencing density and implications of density Source: <sup>85</sup>

However, as argued by Jane Jacobs, in making a recommendation to increase density, it is important to keep in mind one's objective and to define the performance criteria. From a cardiovascular health perspective, the two important performance criteria that need to be considered are: a built form that encourages more walking; and a built form that increases access to shops and services and public transport, as the latter are associated with more walking and active forms of transportation.

### **So what level of density is optimal from a cardiovascular health perspective?**

Based on the limited available evidence and consistent practice advice, we are able to make a number of recommendations:

#### **Recommendations:**

1. While empirical evidence is very limited, there is agreement using a practice-based case study approach and one empirical Australian study that a minimum net density threshold of 20 dwellings per hectare (or gross density of 18 dwellings per hectare) is the minimum required to encourage walking.
2. If an additional performance criteria required that densities are sufficient to make amenities and public transport viable on the basis that increased access to amenities and public transport will encourage more walking (as was shown in this report), then dwelling densities of between 35-43 net and 32-40 gross dwellings per hectare (based on housing occupancies of 2.6 persons/dwelling) are required.
3. It is further recommended that dwelling density not be considered in isolation of the other critical built environment attributes required to increase walking, cycling and public transport use. Density is necessary, but insufficient alone to bring about change. Rather, we recommend that the Heart Foundation actively promote consideration of the 6Ds: i.e., density, distance to transit, destination accessibility, diversity, design, and demand management as it is the *cumulative effects* of these attributes that create the pedestrian-friendly areas required to increase levels of physical activity and in turn, reduce the risk of cardiovascular disease.



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